CHAPTER XVIII

Hypotheses

Section 1. An Hypothesis, sometimes employed instead of a known law, as a premise in the deductive investigation of nature, is defined by Mill as “any supposition which we make (either without actual evidence, or on evidence avowedly insufficient) in order to endeavour to deduce from it conclusions in accordance with facts which are known to be real; under the idea that if the conclusions to which the hypothesis leads are known truths, the hypothesis itself either must be, or at least is likely to be, true.” The deduction of known truths from an hypothesis is its Verification; and when this has been accomplished in a good many cases, and there are no manifest failures, the hypothesis is often called a Theory; though this term is also used for the whole system of laws of a certain class of phenomena, as when Astronomy is called the ‘theory of the heavens.’ Between hypothesis and theory in the former sense no distinct line can be drawn; for the complete proof of any speculation may take a long time, and meanwhile the gradually accumulating evidence produces in different minds very different degrees of satisfaction; so that the sanguine begin to talk of ‘the theory,’ whilst the circumspect continue to call it ‘the hypothesis.’

An Hypothesis may be made concerning (1) an Agent, such as the ether; or (2) a Collocation, such as the plan of our solar system–whether geocentric or heliocentric; or (3) a Law of an agent’s operation, as that light is transmitted by a wave motion of such lengths or of such rates of vibration.

The received explanation of light involves both an agent, the ether, as an all-pervading elastic fluid, and also the law of its operation, as transmitting light in waves of definite form and length, with definite velocity. The agreement between the calculated results of this complex hypothesis and the observed phenomena of light is the chief part of the verification; which has now been so successfully accomplished that we generally hear of the ‘Undulatory Theory.’ Sometimes a new agent only is proposed; as the planet Neptune was at first assumed to exist in order to account for perturbations in the movements of Uranus, influencing it according to the already established law of gravitation. Sometimes the agents are known, and only the law of their operation is hypothetical, as was at first the case with the law of gravitation itself. For the agents, namely, Earth, falling bodies on the Earth, Moon, Sun, and planets were manifest; and the hypothesis was that their motions might be due to their attracting one another with a force inversely proportional to the squares of the distances between them. In the Ptolemaic Astronomy, again, there was an hypothesis as to the collocation of the heavenly bodies (namely, that our Earth was the centre of the universe, and that Moon, Sun, planets and stars revolved around her): in the early form of the system there was also an hypothesis concerning agents upon which this arrangement depended (namely, the crystalline spheres in which the heavenly bodies were fixed, though these were afterwards declared to be imaginary); and an hypothesis concerning the law of operation (namely, that circular motion is the most perfect and eternal, and therefore proper to celestial things).

Hypotheses are by no means confined to the physical sciences: we all make them freely in private life. In searching for anything, we guess where it may be before going to look for it: the search for the North Pole was likewise guided by hypotheses how best to get there. In estimating the characters or explaining the conduct of acquaintances or of public men, we frame hypotheses as to their dispositions and principles. 'That we should not impute motives' is a peculiarly absurd maxim, as there is no other way of understanding human life. To impute bad motives, indeed, when good are just as probable, is to be wanting in the scientific spirit, which views every subject in 'a dry light.' Nor can we help 'judging others by ourselves'; for self-knowledge is the only possible starting-point when we set out to interpret the lives of others. But to understand the manifold combinations of which the elements of character are susceptible, and how these are determined by the breeding of race or family under various conditions, and again by the circumstances of each man's life, demands an extraordinary union of sympathetic imagination with scientific habits of thought. Such should be the equipment of the historian, who pursues the same method of hypothesis when he attempts to explain (say) the state of parties upon the Exclusion

Bill, or the policy of Louis XI. Problems such as the former of these are the easier; because, amidst the compromises of a party, personal peculiarities obliterate one another, and expose a simpler scheme of human nature with fewer fig-leaves. Much more hazardous hypotheses are necessary in interpreting the customs of savages, and the feelings of all sorts of animals. Literary criticisms, again, abound with hypotheses: e.g., as to the composition of the Homeric poems, the order of the Platonic dialogues, the authorship of the Caedmonic poems, or the Ossianic, or of the letters of Junius. Thus the method of our everyday thoughts is identical with that of our most refined speculations; and in every case we have to find whether the hypothesis accounts for the facts.

Section 2. It follows from the definition of an hypothesis that none is of any use that does not admit of verification (proof or disproof), by comparing the results that may be deduced from it with facts or laws. If so framed as to elude every attempt to test it by facts, it can never be proved by them nor add anything to our understanding of them.

Suppose that a conjurer asserts that his table is controlled by the spirit of your deceased relative, and makes it rap out an account of some adventure that could not easily have been within a stranger's knowledge. So far good. Then, trying again, the table raps out some blunder about your family which the deceased relative could not have committed; but the conjurer explains that 'a lying spirit' sometimes possesses the table. This amendment of the hypothesis makes it equally compatible with success and with failure. To pass from small things to great, not dissimilar was the case of the Ptolemaic Astronomy: by successive modifications, its hypothesis was made to correspond with accumulating observations of the celestial motions so ingeniously that, until the telescope was invented, it may be said to have been unverifiable. Consider, again, the sociological hypothesis, that civil order was at first founded on a Contract which remains binding upon all mankind: this is reconcilable with the most opposite institutions. For we have no record of such an event: and if the institutions of one State (say the British) include ceremonies, such as the coronation oath and oath of allegiance, which may be remnants of an original contract, they may nevertheless be of comparatively recent origin; whereas if the institutions of another State (say the Russian) contain nothing that admits of similar interpretation, yet traces of the contract once existing may long since have been obliterated. Moreover, the actual contents of the contract not having been preserved, every adherent of this hypothesis supplies them at his own discretion, 'according to the dictates of Reason'; and so one derives from it the duty of passive obedience, and another with equal cogency establishes the right of rebellion.

To be verifiable, then, an hypothesis must be definite; if somewhat vague in its first conception (which is reasonably to be expected), it must be made definite in order to be put to the proof. But, except this condition of verifiability, and definiteness for the sake of verifiability, without which a proposition does not deserve the name of an hypothesis, it seems inadvisable to lay down rules for a 'legitimate' hypothesis. The epithet is misleading. It suggests that the Logician makes rules for scientific inquirers; whereas his business is to discover the principles which they, in fact, employ in what are acknowledged to be their most successful investigations. If he did make rules for them, and they treated him seriously, they might be discouraged in the exercise of that liberty of hypothesising which is the condition of all originality; whilst if they paid no attention to him, he must suffer some loss of dignity. Again, to say that a 'legitimate hypothesis' must explain all the facts, at least in the department for which it is invented, is decidedly discouraging. No doubt it may be expected to do this in the long run when (if ever) it is completely established; but this may take a long time: is it meanwhile illegitimate? Or can this adjective be applied to Newton's corpuscular theory of light, even though it has failed to explain all the facts?

Section 3. Given a verifiable hypothesis, however, what constitutes proof or disproof?

(1) If a new agent be proposed, it is desirable that we should be able directly to observe it, or at least to obtain some evidence of its existence of a different kind from the very facts which it has been invented to explain. Thus, in the discovery of Neptune, after the existence of such a planet outside the orbit of Uranus had been conjectured (to account for the movements of the latter), the place

in the heavens which such a body should occupy at a certain time was calculated, and there by means of the telescope it was actually seen.

Agents, however, are assumed and reasoned upon very successfully which, by their nature, never can be objects of perception: such are the atoms of Chemistry and the ether of Optics. But the severer methodologists regard them with suspicion: Mill was never completely convinced about the ether; the defining of which has been found very difficult. He was willing, however, to make the most of the evidence that has been adduced as indicating a certain property of it distinct from those by which it transmits radiation, namely, mechanical inertia, whereby it has been supposed to retard the career of the heavenly bodies, as shown especially by the history of Encke's comet. This comet returned sooner than it should, as calculated from the usual data; the difference was ascribed to the influence of a resisting medium in reducing the extent of its orbit; and such a medium may be the ether. If this conjecture (now of less credit) should gain acceptance, the ether might be regarded as a vera causa (that is, a condition whose existence may be proved independently of the phenomena it was intended to explain), in spite of its being excluded by its nature from the sphere of direct perception. However, science is not a way of perceiving things, but essentially a way of thinking about them. It starts, indeed, from perception and returns to it, and its thinking is controlled by the analogies of perception. Atoms and ether are thought about as if they could be seen or felt, not as noumena; and if still successful in connecting and explaining perceptions, and free from contradiction, they will stand as hypotheses on that ground.

On the other hand, a great many agents, once assumed in order to explain phenomena, have since been explained away. Of course, a fact can never be 'explained away': the phrase is properly applicable to the fate of erroneous hypotheses, when, not only are they disproved, but others are established in their places. Of the Aristotelian spheres, which were supposed to support and translate sun, moon and planets, no trace has ever been found: they would have been very much in the way of the comets. Phlogiston, again, an agent much in favour with the earlier Chemists, was found, Whewell tells us, when their theories were tested by exact weighing, to be not merely non-existent but a minus quantity; that is to say, it required the assumption of its absolute lightness "so that it diminished the weight of the compounds into which it entered." These agents, then, the spheres and phlogiston, have been explained away, and instead of them we have the laws of motion and oxygen.

(2) Whether the hypothetical agent be perceptible or not, it cannot be established as a cause, nor can a supposed law of such an agent be accepted as sufficient to the given inquiry, unless it is adequate to account for the effects which it is called upon to explain, at least so far as it pretends to explain them. The general truth of this is sufficiently obvious, since to explain the facts is the purpose of an hypothesis; and we have seen that Newton gave up his hypothesis that the moon was a falling body, as long as he was unable to show that the amount of its deflection from a tangent (or fall) in a given time, was exactly what it should be, if the Moon was controlled by the same force as falling bodies on the Earth.

It is important to observe the limitations to this canon. In the first place, it says that, unless adequate to explain the facts in question, an hypothesis cannot be 'established'; but, for all that, such an hypothesis may be a very promising one, not to be hastily rejected, since it may take a very long time fully to verify an hypothesis. Some facts may not be obtainable that are necessary to show the connection of others: as, for example, the hypothesis that all species of animals have arisen from earlier ones by some process of gradual change, can be only imperfectly verified by collecting the fossil remains of extinct species, because immense depths and expanses of fossiliferous strata have been destroyed. Or, again, the general state of culture may be such as to prevent men from tracing the consequences of an hypothesis; for which reason, apparently, the doctrine that the Sun is the centre of our planetary system remained a discredited hypothesis for 2000 years. This should instruct us not to regard an hypothesis as necessarily erroneous or illegitimate merely because we cannot yet see how it works out: but neither can we in such a case regard it as established, unless we take somebody's word for it.

Secondly, the canon says that an hypothesis is not established, unless it accounts for the phenomena so far as it professes to. But it implies a complete misunderstanding to assail a doctrine for not explaining what lies beyond its scope. Thus, it is no objection to a theory of the origin of species, that it does not explain the origin of life: it does not profess to. For the same reason, it is no objection to the theory of Natural Selection, that it does not account for the variations which selection presupposes. But such objections might be perfectly fair against a general doctrine of Evolution.

An interesting case in Wallace's Darwinism (chap. x.) will illustrate the importance of attending to the exact conditions of an hypothesis. He says that in those groups of "birds that need protection from enemies," "when the male is brightly coloured and the female sits exposed on the nest, she is always less brilliant and generally of quite sober and protective hues"; and his hypothesis is, that these sober hues have been acquired or preserved by Natural Selection, because it is important to the family that the sitting bird should be inconspicuous. Now to this it might be objected that in some birds both sexes are brilliant or conspicuous; but the answer is that the female of such species does not sit exposed on the nest; for the nests are either domed over, or made in a hole; so that the sitting bird does not need protective colouring. If it be objected, again, that some sober-coloured birds build domed nests, it may be replied that the proposition 'All conspicuously coloured birds are concealed in the nest,' is not to be converted simply into 'All birds that sit concealed in the nest are conspicuously coloured.' In the cases alleged the domed nests are a protection against the weather, and the sober colouring is a general protection to the bird, which inhabits an open country. It may be urged, however, that jays, crows, and magpies are conspicuous birds, and yet build open nests: but these are aggressive birds, not needing protection from enemies. Finally, there are cases, it must be confessed, in which the female is more brilliant than the male, and which yet have open nests. Yes: but then the male sits upon the eggs, and the female is stronger and more pugnacious!

Thus every objection is shown to imply some inattention to the conditions of the hypothesis; and in each case it may be said, exceptio probat regulam–the exception tests the rule. (Of course, the usual translation "proves the rule," in the restricted modern sense of "prove," is absurd.) That is to say, it appears on examination: (1) that the alleged exception is not really one, and (2) that it stands in such relation to the rule as to confirm it. For to all the above objections it is replied that, granting the phenomenon in question (special protective colouring for the female) to be absent, the alleged cause (need of protection) is also absent; so that the proof is, by means of the objections, extended, from being one by the method of Agreement, into one by the Double Method.

Thirdly, an hypothesis originally intended to account for the whole of a phenomenon and failing to do so, though it cannot be established in that sense, may nevertheless contain an essential part of the explanation. The Neptunian Hypothesis in Geology, was an attempt to explain the formation of the Earth's outer crust, as having been deposited from an universal ocean of mud. In the progress of the science other causes, seismic, fluvial and atmospheric, have been found necessary in order to complete the theory of the history of the Earth's crust; but it remains true that the stratified rocks, and some that have lost their stratified character, were originally deposited under water. Inadequacy, therefore, is not a reason for entirely rejecting an hypothesis or treating it as illegitimate.

(3) Granting that the hypothetical cause is real and adequate, the investigation is not complete. Agreement with the facts is a very persuasive circumstance, the more so the more extensive the agreement, especially if no exceptions are known. Still, if this is all that can be said in favour of an hypothesis, it amounts to proof at most by the method of Agreement; it does not exclude the possibility of vicarious causes; and if the hypothesis proposes a new agent that cannot be directly observed, an equally plausible hypothesis about another imagined agent may perhaps be invented.

According to Whewell, it is a strong mark of the truth of an hypothesis when it agrees with distinct inductions concerning different classes of facts, and he calls this the 'Consilience of Inductions,' because they jump together in the unity of the hypothesis. It is particularly convincing when this consilience takes place easily and naturally without necessitating the mending and tinkering of the hypothesis; and he cites the Theory of Gravitation and the Undulatory Theory of Light as the most conspicuous examples of such ever-victorious hypotheses. Thus, gravitation explains the fall of bodies on the Earth, and the orbits of the planets and their satellites; it applies to the tides, the comets, the double stars, and gives consistency to the Nebular Hypothesis, whence flow important geological inferences; and all this without any need of amendment. Nevertheless, Mill, with his rigorous sense of duty, points out, that an induction is merely a proposition concerning many facts, and that a consilience of inductions is merely a multiplication of the facts explained; and that, therefore, if the proof is merely Agreement in each case, there can be no more in the totality; the possibility of vicarious causes is not precluded; and the hypothesis may, after all, describe an accidental circumstance.

Whewell also laid great stress upon prediction as a mark of a true hypothesis. Thus, Astronomers predict eclipses, occultations, transits, long beforehand with the greatest precision; and the prediction of the place of Neptune by sheer force of deduction is one of the most astonishing things in the history of science. Yet Mill persisted in showing that a predicted fact is only another fact, and that it is really not very extraordinary that an hypothesis, that happens to agree with many known facts, should also agree with some still undiscovered. Certainly, there seems to be some illusion in the common belief in the probative force of prediction. Prediction surprises us, puts us off our guard, and renders persuasion easy; in this it resembles the force of an epigram in rhetoric. But cases can be produced in which erroneous hypotheses have led to prediction; and Whewell himself produces them. Thus, he says that the Ptolemaic theory was confirmed by its predicting eclipses and other celestial phenomena, and by leading to the construction of Tables in which the places of the heavenly bodies were given at every moment of time. Similarly, both Newton's theory of light and the chemical doctrine of phlogiston led to predictions which came true.

What sound method demands in the proof of an hypothesis, then, is not merely that it be shown to agree with the facts, but that every other hypothesis be excluded. This, to be sure, may be beyond our power; there may in some cases be no such negative proof except the exhaustion of human ingenuity in the course of time. The present theory of colour has in its favour the failure of Newton's corpuscular hypothesis and of Goethe's anti-mathematical hypothesis; but the field of conjecture remains open. On the other hand, Newton's proof that the solar system is controlled by a central force, was supported by the demonstration that a force having any other direction could not have results agreeing with Kepler's second law of the planetary motions, namely, that, as a planet moves in its orbit, the areas described by a line drawn from the sun to the planet are proportional to the times occupied in the planet's motion. When a planet is nearest to the sun, the area described by such a line is least for any given distance traversed by the planet; and then the planet moves fastest: when the planet is furthest from the sun, the area described by such a line is greatest for an equal distance traversed; and then the planet moves slowest. This law may be deduced from the hypothesis of a central force, but not from any other; the proof, therefore, as Mill says, satisfies the method of Difference.

Apparently, to such completeness of demonstration certain conditions are necessary: the possibilities must lie between alternatives, such as A or not-A, or amongst some definite list of cases that may be exhausted, such as equal, greater or less. He whose hypothesis cannot be brought to such a definite issue, must try to refute whatever other hypotheses are offered, and naturally he will attack first the strongest rivals. With this object in view he looks about for a "crucial instance," that is, an observation or experiment that stands like a cross (sign-post) at the parting of the ways to guide us into the right way, or, in plain words, an instance that can be explained by one hypothesis but not by another. Thus the phases of Venus, similar to those of the Moon, but concurring with great changes of apparent size, presented, when discovered by Galileo, a crucial instance in favour of the Copernican hypothesis, as against the Ptolemaic, so far at least as to prove that Venus revolved around the Sun inside the orbit of the Earth. Foucault's experiment determining the velocity of Light (cited in the last chapter) was at first intended as an experimentum crucis to decide between the corpuscular and undulatory theories; and answered this purpose, by showing that the velocity of a beam passed through water was less than it should be by the former, but in agreement with the latter doctrine (Deschanel: Section 813).

Perhaps experiments of this decisive character are commonest in Chemistry: chemical tests, says Herschel, "are almost universally crucial experiments." The following is abridged from Playfair (Encycl. Met., Diss. III.): The Chemists of the eighteenth century observed that metals were rendered heavier by calcination; and there were two ways of accounting for this: either something had been added in the process, though what, they could not imagine; or, something had been driven off that was in its nature light, namely, phlogiston. To decide between these hypotheses, Lavoisier hermetically sealed some tin in a glass retort, and weighed the whole. He then heated it; and, when the tin was calcined, weighed the whole again, and found it the same as before. No substance, therefore, either light or heavy, had escaped. Further, when the retort was cooled and opened, the air rushed in, showing that some of the air formerly within had disappeared or lost its elasticity. On weighing the whole again, its weight was now found to have increased by ten grains; so that ten grains of air had entered when it was opened. The calcined tin was then weighed separately, and proved to be exactly ten grains heavier than when it was placed in the retort; showing that the ten grains of air that had disappeared had combined with the metal during calcination. This experiment, then, decided against phlogiston, and led to an analysis of common air confirming Priestley's discovery of oxygen.

(4) An hypothesis must agree with the rest of the laws of Nature; and, if not itself of the highest generality, must be derivable from primary laws (chap. xix. Section 1). Gravitation and the diffusion of heat, light and sound from a centre, all follow the 'law of the inverse square,' and agree with the relation of the radius of a sphere to its surface. Any one who should think that he had discovered a new central force would naturally begin to investigate it on the hypothesis that it conformed to the same law as gravitation or light. A Chemist again, who should believe himself to have discovered a new element, would expect it to fill one of the vacant places in the Periodic Table. Conformity, in such cases, is strong confirmation, and disagreement is an occasion of

misgivings.

A narrower hypothesis, as 'that the toad's ugliness is protective', would be supported by the general theory of protective colouring and figure, and by the still more general theory of Natural Selection, if facts could be adduced to show that the toad's appearance does really deter its enemies. Such an hypothesis resembles an Empirical Law in its need of derivation (chap. xix. SectionSection 1, 2). If underivable from, or irreconcilable with, known laws, it is a mere conjecture or prejudice. The absolute leviation of phlogiston, in contrast with the gravitation of all other forms of matter, discredited that supposed agent. That Macpherson should have found the Ossianic poems extant in the Gaelic memory, was contrary to the nature of oral tradition; except where tradition is organised, as it was for ages among the Brahmins. The suggestion that xanthochroid Aryans were "bleached" by exposure during the glacial period, does not agree with Wallace's doctrine concerning the coloration of Arctic animals. That our forefathers being predatory, like bears, white variations amongst them were then selected by the advantage of concealment, is a more plausible hypothesis.

Although, then, the consilience of Inductions or Hypotheses is not a sufficient proof of their truth, it is still a condition of it; nonconsilience is a suspicious circumstance, and resilience (so to speak), or mutual repugnance, is fatal to one or all.

Section 4. We have now seen that a scientific hypothesis, to deserve the name, must be verifiable and therefore definite; and that to establish itself as a true theory, it must present some symptom of reality, and be adequate and exclusive and in harmony with the system of experience. Thus guarded, hypotheses seem harmless enough; but some people have a strong prejudice against them, as against a tribe of savages without government, or laws, or any decent regard for vested interests. It is well known, too, that Bacon and Newton disparaged them. But Bacon, in his examples of an investigation according to his own method, is obliged, after a preliminary classification of facts, to resort to an hypothesis, calling it permissio intellectus, interpretatio inchoata or vindemiatio prima. And Newton when he said hypotheses non fingo, meant that he did not deal in fictions, or lay stress upon supposed forces (such as 'attraction'), that add nothing to the law of the facts. Hypotheses are essential aids to discovery: speaking generally, deliberate investigation depends wholly upon the use of them.

It is true that we may sometimes observe a train of events that chances to pass before us, when either we are idle or engaged with some other inquiry, and so obtain a new glimpse of the course of nature; or we may try experiments haphazard, and watch the results. But, even in these cases, before our new notions can be considered knowledge, they must be definitely framed in hypotheses and reobserved or experimented upon, with whatever calculations or precautions may be necessary to ensure accuracy or isolation. As a rule, when inquiring deliberately into the cause of an event, whether in nature or in history, we first reflect upon the circumstances of the case and compare it with similar ones previously investigated, and so are guided by a preconception more or less definite of 'what to look for,' what the cause is likely to be, that is, by an hypothesis. Then, if our preconception is justified, or something which we observe leads to a new hypothesis, either we look for other instances to satisfy the canons of Agreement; or (if the matter admits of experiment) we endeavour, under known conditions according to the canon of Difference, to reproduce the event by means of that which our hypothesis assigns as the cause; or we draw remote inferences from our hypothesis, and try to test these by the Inductive Canons.

If we argue from an hypothesis and express ourselves formally, it will usually appear as the major premise; but this is not always the case. In extending ascertained laws to fresh cases, the minor premise may be an hypothesis, as in testing the chemical constitution of any doubtful substance, such as a piece of ore. Some solution or preparation, A, is generally made which (it is known) will, on the introduction of a certain agent, B, give a reaction, C, if the preparation contains a given substance, X. The major premise is the law of reaction– Whenever A is X, if treated with B it is C.

The minor premise is an hypothesis that the preparation contains

X. An experiment then treats A with B. If C result, a probability is raised in favour of the hypothesis that A is X; or a certainty, if we know that C results on that condition only.

So important are hypotheses to science, that Whewell insists that they have often been extremely valuable even though erroneous. Of the Ptolemaic system he says, “We can hardly imagine that Astronomy could, in its outset, have made so great a progress under any other form.” It served to connect men’s thoughts on the subject and to sustain their interest in working it out; by successive corrections “to save appearances,” it attained at last to a descriptive sort of truth, which was of great practical utility; it also occasioned the invention of technical terms, and, in general digested the whole body of observations and prepared them for assimilation by a better hypothesis in the fulness of time. Whewell even defends the maxim that “Nature abhors a vacuum,” as having formerly served to connect many facts that differ widely in their first aspect. “And in reality is it not true,” he asks, “that nature does abhor a vacuum, and does all she can to avoid it?” Let no forlorn cause despair of a champion! Yet no one has accused Whewell of Quixotry; and the sense of his position is that the human mind is a rather feeble affair, that can hardly begin to think except with blunders.

The progress of science may be plausibly attributed to a process of Natural Selection; hypotheses are produced in abundance and variety, and those unfit to bear verification are destroyed, until only the fittest survive. Wallace, a practical naturalist, if there ever was one, as well as an eminent theorist, takes the same view as Whewell of such inadequate conjectures. Of ‘Lemuria,’ an hypothetical continent in the Indian Ocean, once supposed to be traceable in the islands of Madagascar, Seychelles, and Mauritius, its surviving fragments, and named from the Lemurs, its characteristic denizens, he says (Island Life, chap. xix.) that it was “essentially a provisional hypothesis, very useful in calling attention to a remarkable series of problems in geographical distribution [of plants and animals], but not affording the true solution of those problems.” We see, then, that ‘provisional hypotheses,’ or working hypotheses,’ though erroneous, may be very useful or (as Whewell says) necessary.

Hence, to be prolific of hypotheses is the first attribute of scientific genius; the first, because without it no progress whatever can be made. And some men seem to have a marked felicity, a sort of instinctive judgment even in their guesses, as if their heads were made according to Nature. But others among the greatest, like Kepler, guess often and are often wrong before they hit upon the truth, and themselves, like Nature, destroy many vain shoots and seedlings of science for one that they find fit to live. If this is how the mind works in scientific inquiry (as it certainly is, with most men, in poetry, in fine art, and in the scheming of business), it is useless to complain. We should rather recognise a place for fools' hypotheses, as Darwin did for "fools' experiments." But to complete the scientific character, there must be great patience, accuracy, and impartiality in examining and testing these conjectures, as well as great ingenuity in devising experiments to that end. The want of these qualities leads to crude work and public failure and brings hypotheses into derision. Not partially and hastily to believe in one's own guesses, nor petulantly or timidly to reject them, but to consider the matter, to suspend judgment, is the moral lesson of science: difficult, distasteful, and rarely mastered.

Section 5. The word 'hypothesis' is often used also for the scientific device of treating an Abstraction as, for the purposes of argument, equivalent to the concrete facts. Thus, in Geometry, a line is treated as having no breadth; in Mechanics, a bar may be supposed absolutely rigid, or a machine to work without friction; in Economics, man is sometimes regarded as actuated solely by love of gain and dislike of exertion. The results reached by such reasoning may be made applicable to the concrete facts, if allowance be made for the omitted circumstances or properties, in the several cases of lines, bars, and men; but otherwise all conclusions from abstract terms are limited by their definitions. Abstract reasoning, then (that is, reasoning limited by definitions), is often said to imply 'the hypothesis' that things exist as their names are defined, having no properties but those enumerated in their definitions. This seems, however, a needless and confusing extension of the term; for an hypothesis proposes an agent, collocation, or law hitherto unknown; whereas abstract reasoning proposes to exclude from consideration a good deal that is well known. There seems no reason why the latter device should not be plainly called an Abstraction.

Such abstractions are necessary to science; for no object is comprehensible by us in all its properties at once. But if we forget the limitations of our abstract data, we are liable to make strange blunders by mistaking the character of the results: treating the results as simply true of actual things, instead of as true of actual things only so far as they are represented by the abstractions. In addressing abstract reasoning, therefore, to those who are unfamiliar with scientific methods, pains should be taken to make it clear what the abstractions are, what are the consequent limitations upon the argument and its conclusions, and what corrections and allowances are necessary in order to turn the conclusions into an adequate account of the concrete facts. The greater the number, variety, and subtlety of the properties possessed by any object (such as human nature), the greater are the qualifications required in the conclusions of abstract reasoning, before they can hold true of such an object in practical affairs.

Closely allied to this method of Abstraction is the Mathematical Method of Limits. In his History of Scientific Ideas (B. II. c. 12), Whewell says: "The Idea of a Limit supplies a new mode of establishing mathematical truths. Thus with regard to the length of any portion of a curve, a problem which we have just mentioned; a curve is not made up of straight lines, and therefore we cannot by means of any of the doctrines of elementary geometry measure the length of any curve. But we may make up a figure nearly resembling any curve by putting together many short straight lines, just as a polygonal building of very many sides may nearly resemble a circular room. And in order to approach nearer and nearer to a curve, we may make the sides more and more small, more and more numerous. We may then possibly find some mode of measurement, some relation of these small lines to other lines, which is not disturbed by the multiplication of the sides, however far it be carried. And thus we may do what is equivalent to measuring the curve itself; for by multiplying the sides we may approach more and more closely to the curve till no appreciable difference remains. The curve line is the Limit of the polygon; and in this process we proceed on the Axiom that 'What is true up to the Limit is true at the Limit.'"

What Whewell calls the Axiom here, others might call an Hypothesis; but perhaps it is properly a Postulate. And it is just the obverse of the Postulate implied in the Method of Abstractions, namely, that 'What is true of the Abstraction is true of concrete cases the more nearly they approach the Abstraction.' What is true of the 'Economic Man' is truer of a broker than of a farmer, of a farmer than of a labourer, of a labourer than of the artist of romance. Hence the Abstraction may be called a Limit or limiting case, in the sense that it stands to concrete individuals, as a curve does to the figures made up "by putting together many short straight lines." Correspondingly, the Proper Name may be called the Limit of the class-name; since its attributes are infinite, whereas any name whose attributes are less than infinite stands for a possible class. In short, for logical purposes, a Limit may be defined as any extreme case to which actual examples may approach without ever reaching it. And in this sense 'Method of Limits' might be used as a term including the Method of Abstractions; though it would be better to speak of them generically as 'Methods of Approximation.'

We may also notice the Assumptions (as they may be called) that are sometimes employed to facilitate an investigation, because some definite ground must be taken and nothing better can be thought of: as in estimating national wealth, that furniture is half the value of the houses.

It is easy to conceive of an objector urging that such devices as the above are merely ways of avoiding the actual problems, and that they display more cunning than skill. But science, like good sense, puts up with the best that can be had; and, like prudence, does not reject the half-loaf. The position, that a conceivable case that can be dealt with may, under certain conditions, be substituted for one that is unworkable, is a touchstone of intelligence. To stand out for ideals that are known to be impossible, is only an excuse for doing nothing at all.

In another sense, again, the whole of science is sometimes said to be hypothetical, because it takes for granted the Uniformity of

Nature; for this, in its various aspects, can only be directly ascertained by us as far as our experience extends; whereas the whole value of the principle of Uniformity consists in its furnishing a formula for the extension of our other beliefs beyond our actual experience. Transcendentalists, indeed, call it a form of Reason, just because it is presupposed in all knowledge; and they and the Empiricists agree that to adduce material evidence for it, in its full extent, is impossible. If, then, material evidence is demanded by any one, he cannot regard the conclusions of Mathematics and Physical Science as depending on what is itself unproved; he must, with Mill, regard these conclusions as drawn "not from but according to" the axioms of Equality and Causation. That is to say, if the axioms are true, the conclusions are; the material evidence for both the axioms and the conclusions being the same, namely, uncontradicted experience. Now when we say, 'If Nature is uniform, science is true,' the hypothetical character of science appears in the form of the statement. Nevertheless, it seems undesirable to call our confidence in Nature's uniformity an 'hypothesis': it is incongruous to use the same term for our tentative conjectures and for our most indispensable beliefs. 'The Universal Postulate' is a better term for the principle which, in some form or other, every generalisation takes for granted.

We are now sometimes told that, instead of the determinism and continuity of phenomena hitherto assumed by science, we should recognise indeterminism and discontinuity. But it will be time enough to fall in with this doctrine when its advocates produce a new Logic of Induction, and explain the use of the method of Difference and of control experiments according to the new postulates.